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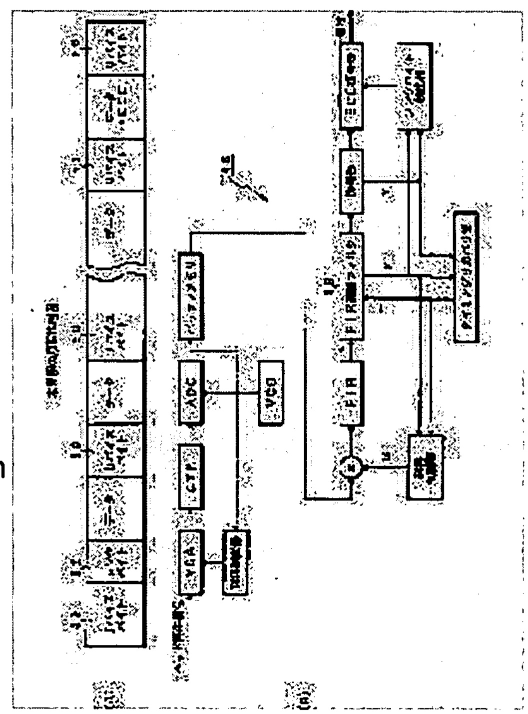
(54) INFORMATION RECORDING AND REPRODUCING DEVICE, SIGNAL DECODING CIRCUIT AND RECORDING STRUCTURE OF INFORMATION RECORDING MEDIUM AND RECORDING METHOD

(57)Abstract:



PROBLEM TO BE SOLVED: To improve decoding performance without using an RLL coding by conducting a stable clock extraction with respect to the deterioration of the SN ratio of signals and by making amplitude correction.

SOLUTION: During a data recording, a data recording section inserts a revise byte 50 that is a beforehand determined specific code string, into equal to or more than two places including the leading and the last section of data and records the byte 50 on a medium. During a data reproducing, a data reproducing section 48 obtains discrete head reproducing signals using a clock and conducts clock extracting and amplitude correction using the signals corresponding to the byte 50 that is the specific code string. In principle, the RLL coding for clock extraction and gain following are eliminated and a revise byte consisting of the specific coding string is inserted into the data in place of the RLL coding and recorded on the medium.

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* NOTICES *

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] About the record structure and the approach of information record regenerative apparatus, such as a magnetic disk, MO, an optical disk, and a magnetic tape unit, a signal decoder circuit, and an information record medium, especially this invention relates to the record structure and the approach of the information record regenerative apparatus and signal decoder circuit which perform timing recovery and a gain adjustment, and an information record medium, after sampling a head regenerative signal with an asynchronous clock.
[0002]
[Description of the Prior Art] Drawing 14 is the example of the sector format in the conventional magnetic disk drive, and consists of a preamble 200, the sink cutting tool 202, data 204, ECC206, and a pad 208.
[0003] That is, the specific sign train called a preamble 200 is recorded on the head in a sector format, at the time of playback, a head regenerative signal is used for a preamble 200 considerable the bottom, and level luffing motion of the phase of the timing recovery PLL circuit for a clock extract and a frequency and level luffing motion of the gain in the AGC circuit for amplitude amendment are performed.
[0004] The specific sign train called the sink cutting tool 202 is recorded on the 2nd field, at the time of playback, the sink cutting tool 202 is detected and the head bit of the data 204 following it is presumed.
[0005] In the former, data 204 are changed and recorded on the RLL sign (Run Length Limited Code) which restricted the die length which sign"0" follows for flattery of a clock extract or amplitude amendment. For this reason, the positional information of the head bit of data 204 based on the sink cutting tool 202 is used for decode of a RLL sign.
[0006] MR (Magnetoresi-stive) head is used for the magnetic disk drive in recent years as a head for playback. Since only 30-50nm of MR heads has not surfaced from a disk-media front face, a head may contact and collide with the projection on the front face of a disk etc.
[0007] If contact and a collision take place, since resistance rises with the rise of head temperature, the direct current level of a regenerative signal will be changed sharply. This phenomenon is called a thermal asperity (TA: Thermal Asperity) phenomenon. If TA occurs, the signal of the large amplitude will be inputted, a bad influence will arise in the AGC circuit and PLL circuit which were operating stably until now, and recovery data will be mistaken.
[0008] Even when a sink cutting tool cannot detect by the error of the data based on such thermal asperity (TA), in order for decode to be possible, like the sector format of drawing 15 , the split of the data was carried out to two data 204-1,204-2, and, in addition to the sink cutting tool 202-1, the spare sink cutting tool 202-2 is formed.
[0009] In this case, it is common that the sink cutting tool 202-1,202-2 detaches supposing the case where a regenerative signal continues broadly and deteriorates. Moreover, when the part which contains the sink cutting tool 202-1 at the time of data playback deteriorates, although it cannot get over, the data 204-2 following the sink cutting tool 202-1 are making the die length of data 204-1 below into the

maximum correction capacity of ECC, and correction of them is attained.
[0010] Drawing 16 is the block in the lead channel mounted in the conventional magnetic disk drive as an IC for a data recovery. In the case of data playback, after amplifying the analog voltage from the reproducing head by the pre amplifier of Head IC, it is sent to the lead channel 210.
[0011] By the lead channel 210, conversion to a digital signal is performed via the adjustable gain amplifier (VGA) 212, the CT filter 214 which carries out a low pass filter and functions, and AD converter (ADC) 216.
[0012] After the FIR filter 218 performs waveform equalization succeedingly, a decoder 220 performs Viterbi decoding. The head bit position which the decoded data were decoded with the RLL decoder 222, and was detected with the sink cutting tool detector 230 at this time is used.
[0013] Moreover, in the lead channel 210, the gain control machine 224 for controlling the gain of the timing recovery section 226 equipped with PLL which controls the timing of the clock from the voltage controlled oscillator (VCO) 228 which samples a signal by AD converter 216, and the adjustable gain amplifier 212, and carrying out amplitude amendment is also carried.
[0014] That is, the timing recovery section 226 is the output signal y of the FIR filter 218, and that decision value Y= [0, -1, +1]. It uses, and asks for phase error deltatau, and a voltage controlled oscillator (VCO) 228 is controlled to lose this phase error deltatau.
[0015] moreover, gain error deltagamma -- the output signal y of the FIR filter 218, and decision value Y= [0, -1, +1] It uses and asks, and the control voltage Vg of the gain control machine 224 is adjusted, and the adjustable gain amplifier (VGA) 212 performs amplitude amendment so that gain error deltagamma may be lost.
[0016] Drawing 17 is other examples of a configuration of the conventional lead channel. In this case, to AD converter 216, using a fixed lock, a regenerative signal is asynchronous and a sampling is performed from a voltage controlled oscillator 234. If the FIR filter 218 is followed, an interpolation filter 232 is formed, and it asks for original sampling-time T based on phase error deltatau of the formula (1) for which it asked in the timing recovery section 236, and is asking for the amplitude y in this sampling-time T by interpolation actuation.
[0017]
[Problem(s) to be Solved by the Invention] By the way, in a magnetic disk drive, when the further high density record is aimed at from now on, the record area per bit becomes small and a S/N ratio will fall. For this reason, since many noise components are overlapped also on the output of the FIR filter currently used for waveform equalization of a lead channel, it error-comes to be easy of the judgment result Y in a decoder. In such a case, timing recovery and the feedback system of amplitude amendment serve as unstable actuation, and we are anxious about the problem to which a data recovery is not carried out normally.
[0018] On the other hand, a RLL sign selects the data stream (symbolic language) which restricted continuation of "0" to the data stream which becomes the origin of it, and is constituted. Here, in order to design the efficient sign in consideration of the rate of coding, it is necessary to determine a symbolic language from the context of former data, and the 1-bit error in a symbolic language turns into a two or more bits error in the data stream used as a RLL decoder output at the time of a data recovery. This error propagation has the problem which degrades the effectiveness of ECC remarkably.
[0019] This invention aims at offering the record structure and the approach of the information record regenerative apparatus which enables the clock extract and amplitude amendment which were stabilized to aggravation of the SN ratio of a signal, and improves the decode engine performance, a signal decoder circuit, and an information record medium, without using a RLL sign.
[0020]
[Means for Solving the Problem] Drawing 1 is the principle explanatory view of this invention. This invention is an information record regenerative apparatus which records information on a magnetic-recording medium and is reproduced. At the time of data logging The data-logging section which inserts the RIBAISU cutting tool 50 who is the specific sign train beforehand set like drawing 1 (A) to at least two or more including the head and the backmost part of data, and is recorded on a medium, At the time

of data playback, after a head regenerative signal is discretized using a clock, it is characterized by having a clock extract and the data playback section 48 of drawing 1 (B) which performs amplitude amendment using the signal corresponding to the RIBAISU cutting tool 50 who is a specific sign train. Furthermore, the data-logging section 46 and the data playback section 48 are reproduced after recording on a medium, without encoding user data to a RLL sign.
[0021] Thus, theoretically, this invention inserts into data the RIBAISU cutting tool who loses the RLL sign for a clock extract or gain flattery, changes to this, and consists of a specific sign train, and records him on a medium. Since a RIBAISU cutting tool is a known data stream, the clock extract which did not mistake a decision value Y, and was stabilized even when the SN ratio of a regenerative signal was bad, and the amplitude amendment of him are attained. Moreover, since it does not have a RLL decoder, the error propagation by RLL decode can be lost and it becomes possible to demonstrate original ECC correction capacity.
[0022] The clock extract by the data playback section 48 asks for original sampling-time T based on the topology extracted from the signal corresponding to a specific sign train, and samples again the signal amplitude which carried out clock synchronization by interpolation actuation of the FIR interpolation filter 88 by this sampling-time T.
[0023] The data-logging section stations the sink cutting tool 52 in the head location of each data in which the split was carried out by the specific sign train, and records him on a medium, and the data playback section 48 detects the sink cutting tool following a specific sign train, presumes the head bit of data, and takes the synchronization of ECC decode.
[0024] The data-logging section includes a sink cutting tool in a specific sign train, and is recorded on a medium, and the data playback section 48 detects a sink cutting tool from a specific sign train, presumes the head bit of data, and takes the synchronization of decode. Thus, by embedding a sink cutting tool into a RIBAISU cutting tool, a sink cutting tool is distributed and it can respond to degradation of a wide range regenerative signal.
[0025] Using the signal corresponding to a specific sign train, the data playback section 48 asks for the standard deviation and autocorrelation of a signal average value and a noise, and uses them for likelihood count of data decode.
[0026] The data-logging section and the data playback section 48 are constituted from a signal-processing integrated circuit, and a signal-processing integrated circuit is carried in a magnetic disk drive or an optical disk unit.
[0027] This invention is what offers the signal decoder circuit which records information on a magnetic-recording medium and is reproduced. At the time of data logging At the time of data playback, with the data-logging section which inserts the specific sign train beforehand set to at least two or more including the head and the backmost part of data, and is recorded on a medium After a head regenerative signal is discretized using a clock, it is characterized by having a clock extract and the data playback section which performs amplitude amendment using the signal corresponding to a specific sign train. Other descriptions in this signal decoder circuit become the same as an information record regenerative apparatus.
[0028] This invention offers the record structure of an information record medium, and the record signal sequence on a medium is characterized by being the record structure which inserted the specific sign train beforehand set to at least two or more including the head and the backmost part of data.
[0029] This record signal sequence has the record structure which has stationed the sink cutting tool in the head location of each data in which the split was carried out by the specific sign train. Moreover, a record signal sequence may be the record structure where the sink cutting tool was included in the specific sign train.
[0030] This invention is what offers the information record playback approach which records information on an information record medium and is reproduced. At the time of data logging The specific sign train (RIBAISU cutting tool) beforehand set to at least two or more including the head and the backmost part of data is inserted, and it records on a medium. At the time of data playback After a head regenerative signal is discretized using a clock, it is characterized by performing clock extract and

amplitude amendment using the signal corresponding to a specific sign train. Furthermore, it reproduces, after recording on a medium, without encoding user data to a RLL sign.
[0031] Here, the clock extract at the time of data playback finds the original sampling time based on the topology extracted from the signal corresponding to a specific sign train, and samples again the signal amplitude which carried out clock synchronization by interpolation actuation of the interpolation filter by this sampling time.
[0032] At the time of data logging, a sink cutting tool is stationed in the head location of each data in which the split was carried out by the specific sign train, and it records on a medium, and at the time of data playback, the sink cutting tool following a specific sign train is detected, the head bit of data is presumed, and the synchronization of decode is taken.
[0033] Moreover, a sink cutting tool is included in a specific sign train, and it records on a medium, and a sink cutting tool is detected from a specific sign train, the head bit of data is presumed, and you may make it take the synchronization of decode at the time of data playback at the time of data logging.
[0034] Furthermore, at the time of data playback, it asks for the standard deviation and autocorrelation of a signal average value and a noise using the signal corresponding to a specific sign train, and uses for likelihood count of data decode.
[0035]
[Embodiment of the Invention] Drawing 2 is a block diagram of a hard disk drive with which this invention is applied. In drawing 2 , a hard disk drive consists of a SCSI controller 10, drive control 12, and disk enclosure 14. Of course, the interface with a host is not limited to the SCSI controller 10, but can use a proper interface controller.
[0036] The program memory 20, the hard disk controller (HDC) 22, and data buffer 24 which used nonvolatile memory, such as the memory 18 using DRAM or SRAM used as MCU (Maine control unit) 16 and control storage and a flash memory which stores a control program, for the SCSI controller 10 are prepared.
[0037] The drive interface logic 26, DSP28, the lead channel (RDC) 30, and the servo driver 32 are formed in the drive control 12.
[0038] Furthermore, the head IC 34 was formed in disk enclosure 14, and the decode head 36-1 to 36-6 equipped with a recording head and the reproducing head to the head IC 34 is connected.
[0039] The decode head 36-1 to 36-6 is formed to each recording surface of a magnetic disk 38-1 to 38-3, and is moved to the truck location of the arbitration of a magnetic disk 38-1 to 38-3 by the drive of the rotary actuator by VCM40. A magnetic disk 38-1 to 38-3 rotates with constant speed with a spindle motor 42. A formatter and the ECC processing section can be prepared in the hard disk controller 22 of the SCSI controller 10.
[0040] Drawing 3 is the operation gestalt of the sector format used by information record playback of this invention. If it is in this sector format, or more to two including the head and the backmost part of sector data 50-n is inserted. the RIBAISU cutting tool 50-1 using the specific sign train defined beforehand, for example, the sign train of "1010...10", 50-2, and ... the data 54-1 which carried out the split among the adjoining RIBAISU cutting tools, 54-2, and ... 54-n has been arranged and data and ECC56 are further arranged between the last RIBAISU cutting tool 50- (n-1) - 50-n. Moreover, behind the top RIBAISU cutting tool 50-1, the sink cutting tool 52 for presuming the head bit of data at the time of a recovery is stationed.
[0041] a part for the bit by changing into this RLL sign, since data are changed into the RLL sign; if it is in the conventional sector format shown in drawing 14 when the data length of sector format is made into 512 bytes here -- about 256 bits in 512 bytes -- existing .
[0042] On the other hand, if it is in the sector format of this invention of drawing 3 , the RIBAISU cutting tool who newly prepared by this invention about 256 bits currently assigned to the conventional RLL sign from not performing conversion with a RLL sign about user data can be assigned.
[0043] If the number of the RIBAISU cutting tools 50-1 - 50-n in drawing 3 is set to n= 6 here, the split of the user data will be carried out to n= 5 including ECC56. 256 bits of conversion bits with the inside of 512 bytes of data, and a conventional RLL sign -- the RIBAISU cutting tool 50-2 to 50-6 of the 2nd

to the last -- it can assign -- for example, 256/ -- 5 = about 50 bits -- then, it is good. Moreover, what is necessary is just to assign 100-200 bits like the conventional pre amplifier about the top RIBAISU cutting tool 50-1.
[0044] For this reason, even if it arranges the RIBAISU cutting tool 50-1 - 50-n to two or more [including the head and the backmost part of a sector like drawing 3], it can consider as the same size mostly with the size of the sector format which is performing conversion with the conventional RLL sign, and the format effectiveness of a medium does not fall.
[0045] Drawing 4 is other operation gestalten of the sector format used by information record playback of this invention. the RIBAISU sink cutting tool 58-1 who included the sink cutting tool for presuming a data head location in the RIBAISU cutting tool who consists of a specific predetermined sign train arranged to two or more [including the head and the tail end of a sector] if it was in this sector format, 58-2, and ... it is characterized by being referred to as 58-n.
[0046] Thus, even if data missing which can presume more correctly presumption of each head bit position of each data 54-1 by which the split was carried out by embedding a sink cutting tool into a RIBAISU cutting tool - 54-n, and data and ECC56, and can perform ECC processing, and contains a sink cutting tool according to thermal asperity (TA) etc. arises, exact ECC processing can be performed by the sink cutting tool embedded into the normal RIBAISU cutting tool part.
[0047] In addition, the data length of the data 54-1 in the sector format which inserted the RIBAISU cutting tool of drawing 4 and the sink cutting tool 58-1 - 58-n - 54-n, and data and ECC56 of considering as the recovery possible length by ECC is natural.
[0048] Drawing 5 shows the outline of the hard disk controller 22 in the hard disk drive of drawing 2 which used the sector format which inserted drawing 3 or two or more RIBAISU cutting tools of drawing 4 , and a lead channel with the head IC 34, and if it is in this operation gestalt, it has taken for the example the case where Viterbi decoding is performed.
[0049] If a recording system is explained first, as for the user data which become by the binary code of (1, 0), parity will be added by the CRC encoder 60 and the ECC encoder 62 of the hard disk controller 22. A CRC sign is used in order to forbid incorrect correction of ECC.
[0050] Then, it is inputted into the record compensator 64 formed in the data-logging section 46 of the lead channel 30, and write-in compensation for extending some reversal spacing in the part where flux reversal adjoins is performed. And a head IC 34 is driven by the driver 66, the guide current to a recording head is generated, and it records on a medium.
[0051] If it is in the data-logging section 46 of the here conventional lead channel 30, the RLL encoder for stabilizing the clock playback by PLL is formed before the record compensator 64, but the RLL encoder is not formed, in order to insert two or more RIBAISU cutting tools and to perform clock playback based on this RIBAISU cutting tool, as shown in the sector format of drawing 3 and drawing 4 if it is in this invention.
[0052] On the other hand, in the case of playback, after the analog voltage from the reproducing head is recorded by the pre amplifier which was first built in the head IC 34 and which is not illustrated, it is sent to the data playback section 48 of the lead channel 30. The detail of this data playback section 48 is clarified with the block diagram of drawing 6 . The data to which it restored in the data playback section 48 are outputted as decode data through the inspection processing by the error correction by the ECC decoder 68 and the CRC decoder 70 of the hard disk controller 22.
[0053] Drawing 6 is the block diagram having shown the operation gestalt of the data playback section 48 prepared in the lead channel 30 of drawing 5 .
[0054] In drawing 6 , after the head regenerative signal outputted from Head IC is changed into a digital signal via the adjustable gain amplifier 72, the CT filter 74 which functions as low pass filters, and AD converter 76, it is memorized by buffer memory 78 per sector.
[0055] The gain control machine 80 controls the gain of the adjustable gain amplifier 72, and amends a head regenerative signal to the fixed amplitude. Moreover, AD converter 76 sampled the head regenerative signal with the clock from a voltage controlled oscillator 82, and has changed it into the digital signal, and the clock from the voltage controlled oscillator 82 for this sampling is using the head

regenerative signal and the asynchronous fixed clock.
[0056] The sector data stored in buffer memory 78 are read after that, after they receive amplitude amendment in digital one by multiplying the gain G from the gain control machine 92 to a multiplier 84, receive waveform equalization with the FIR filter 86, and are inputted into the FIR interpolation filter 88 as an identification finishing signal x.
[0057] The FIR interpolation filter 88 calculates the signal y with the amplitude in the original sampling time which synchronized with the head regenerative signal based on the original timing T in the head regenerative signal calculated in the timing recovery section 94, and sends the identification wave signal [finishing / this interpolation] y to the Viterbi decoder 90.
[0058] If it is in the Viterbi decoder 90, the right signal Y is judged with the Viterbi algorithm about the signal [finishing / identification] y, and the decode signal Y is outputted to the hard disk controller side of the next step.
[0059] Moreover, the sink cutting tool detector 96 is formed, the sink cutting tool based on the output signal y from the FIR interpolation filter 88 and the judgment signal Y from the Viterbi decoder 90 is detected, and the head bit of the data following a sink cutting tool's detection location is presumed.
[0060] If the detection output of this sink cutting tool detector 96 is in equipment conventionally, the RLL decoder formed following the Viterbi decoder 90 is given, and it is used for that decode, but if it is in this invention, since the RLL decoder is not formed, the detection output of the sink cutting tool detector 96 is given to the ECC decoder 68 formed in the hard disk controller of the next step, and is used for presumption of the head bit of data.
[0061] The gain control machine 92 of drawing 6 asks for gain error deltagamma using decision value Y= (0, -1, +1) from an output signal y and the Viterbi decoder 90 outputted from the FIR interpolation filter 88, and performs amplitude amendment.
[0062] Drawing 8 is the block diagram of the gain control machine 92 of drawing 6 , and consists of a gain error detector 98 and a loop filter 100. The gain error detector 98 is gain error deltagamma by the output signal y of the FIR interpolation filter 88, and the judgment signal Y delta gamma=sgn (yi) and (yi-Yi) Amplitude amendment is performed by computing by (1), changing into Gain G with a loop filter 100, and multiplying by the input signal.
[0063] Drawing 9 is the FIR interpolation filter 88 of drawing 6 , and the block diagram of the timing recovery section 94. The phase judging machine 102 and a loop filter 104 are formed in the timing recovery section 94. The phase judging machine 102 searches for the topology extracted from the signal corresponding to the RIBAISU cutting tool of the output signals y of the FIR interpolation filter 88, it asks for sampling-time T original by giving this topology to a loop filter 104, and the clock extract which performs substantially the sampling of the signal amplitude which synchronized with the original block of a head regenerative signal for the second time by interpolation actuation of the FIR interpolation filter 88 by this sampling-time T is performed.
[0064] The FIR interpolation filter 88 is equipped with k steps of delay circuits 108-1 - 108-k, after it carries out the multiplication of the tap gain C0-Ck given by a multiplier 110-1 - 110-k on the tap gain table 106, takes total by the adder 112-1 - 112-k, and makes this the output signal y.
[0065] It is as follows when the detail for performing a block extract from the signal corresponding to a RIBAISU cutting tool using such an FIR interpolation filter 88 is explained.
[0066] Drawing 10 expresses the sample point and analog wave of the output signal x after being the FIR filter 86 of the head regenerative signal which inserted the RIBAISU cutting tool who shows by the sector format of drawing 3 and equalizing about following RIBAISU cutting tool 50- (n+1) through data RIBAISU cutting tool 50-n and in between.
[0067] the original timing which the white dot expresses the signal point by which the sample was carried out with the asynchronous clock from a voltage controlled oscillator 82 here, and is shown with a broken line -- receiving -- a phase error -- being generated -- combining -- a frequency -- the variation rate is also started.
[0068] If it is in this invention, the processing which presumes the phase error of each signal point of the data which exist in the both sides of data between them based on the topology of located RIBAISU

cutting tool 50-n and RIBAISU cutting tool 50- (n+1), and is amended to the amplitude value of the signal point of original timing is made to perform to the FIR interpolation filter 88.
[0069] That is, if the amplitude and phase of the sampled signal are known, the amplitude of the signal in original timing can be predicted with the FIR interpolation filter 88.
[0070] Here, the amplitude of the signal in the data area between RIBAISU cutting tool 50-n and RIBAISU cutting tool 50- (n+1) is known, and the approach of the phase decision under the conditions that a phase is unknown is explained.
[0071] The phase error of i sample eye in RIBAISU cutting tool 50-n is now set to tau (n, i). When the record sign train of RIBAISU cutting tool 50-n is set to "1010...10", it can be considered that a head regenerative signal is a sign curve. For this reason, if amplitude value of i sample eye is set to a (n, i), the phase error tau (n, i) will be given by the degree type.
[0072]
[Equation 1]

$$\tau(n,i) = \tan^{-1}\left(\frac{a(n,i+1)}{a(n,i)}\right) \qquad (2)$$

[0073] In addition, detection of a phase error is not limited to (2) types, but can be detected by other approaches.
[0074] Next, the phase in the center of RIBAISU cutting tool 50-n is set to tauc, and the error by the noise contained in tauf (however, a frequency presupposes that it is fixed in the range of RIBAISU cutting tool 50-n) and the amplitude sampled further in the phase error by the frequency deviation is set to taue. Each i=0-2m [in RIBAISU cutting tool 50-n] phase error is given by the degree type from these parameters.
[0075]
[Equation 2]

$$\left.\begin{aligned}
\tau(n,0) &= \tau c(n) - m\cdot\tau f(n) + \tau e(n,0)\\
\tau(n,1) &= \tau c(n) - (m-1)\cdot\tau f(n) + \tau e(n,1)\\
&\vdots\\
\tau(n,m-1) &= \tau c(n) - \tau f(n) + \tau e(n,m-1)\\
\tau(n,m) &= \tau c(n) + \tau e(n,m)\\
\tau(n,m+1) &= \tau c(n) + \tau f(n) + \tau e(n,m+1)\\
&\vdots\\
\tau(n,2m-1) &= \tau c(n) + (m-1)\cdot\tau f(n) + \tau e(n,2m-1)\\
\tau(n,2m) &= \tau c(n) + m\cdot\tau f(n) + \tau e(n,2m)
\end{aligned}\right\} \qquad (3)$$

[0076] Since it is considered that the average of the phase error by the noise is 0, it can obtain the following formulas here.
[0077]
[Equation 3]

$$\tau c(n) = \frac{\sum_{i=0, i\neq m}^{i=2m}\tau(n,i)}{2m} + \overline{\tau e(n)} = \frac{\sum_{i=0, i\neq m}^{i=2m}\tau(n,i)}{2m} \qquad (4)$$

$$\tau f(n) = \frac{\sum_{i=0}^{i=m/2-1}\tau(n,2i+1) - \tau(n,2i) + \sum_{i=m/2+1}^{i=m}\tau(n,2i) - \tau(n,2i-1)}{m} \qquad (5)$$

[0078] Therefore, the phase tau (n, j) in the data inserted into RIBAISU cutting tool 50-n and RIBAISU cutting tool 50- (n+1) can be approximated by the degree type.
[0079]
[Equation 4]

$$\tau(n,j) = F(\tau c(n), \tau c(n+1), j) + F(\tau f(n), \tau f(n+1), j) \cdot j \qquad (6)$$

[0080] In this (6) type, Function F (a, b, j) expresses the internal division in j inserted into a and b. Moreover, although only the topology from RIBAISU cutting tool 50-n located in the both sides of data and RIBAISU cutting tool 50- (n+1) was used if it was in this phase determining method, the degree of the approximate expression of (6) types can be raised by taking into consideration the topology of the RIBAISU cutting tool who adjoins other 1 or two or more other both sides, and that precision can be raised.
[0081] Thus, if it is in this invention, even if it is the recovery with an asynchronous clock in inserting and recording a RIBAISU cutting tool into data, presuming the phase of the data located in between from a known RIBAISU cutting tool's topology at the time of playback, and amending to the amplitude of original timing, it can interpolate to the signal amplitude by original timing by which the right sampling was carried out, and the error rate as decode engine performance in Viterbi decoding can be raised.
[0082] Moreover, since the RLL sign is not used, original ECC correction capacity can fully be demonstrated by spreading, in case the bit error in the RLL symbolic language at the time of a data recovery is decoding, not becoming a two or more bits error, and losing the error propagation with a RLL sign.
[0083] Drawing 11 is the explanatory view of the operation gestalt of this invention which calculates and offers the parameter for the likelihood count in a decoder from a RIBAISU cutting tool's correspondence signal. In drawing 11 , to the Viterbi decoder 116, if it is in this operation gestalt, the noise correlation operation part 114 is newly formed.
[0084] The noise correlation operation part 114 incorporates the signal corresponding to the RIBAISU cutting tool of the output signals y with which the phase correction outputted from the FIR interpolation filter 88 of drawing 6 ended as a training signal sequence. It is based on the signal sequence corresponding to this RIBAISU cutting tool. The signal average d The standard deviation sigma of a noise and the correlation coefficient e of an autocorrelation are calculated, the Viterbi decoder 116 is given by making these into a noise correlation parameter, and it is used for the likelihood count for decoding data from the signal corresponding to a part for the data division inserted into the RIBAISU cutting tool.
[0085] The Viterbi decoding of a noise prediction mold is realizable by specifically using the average value d calculated by the noise correlation operation part 114 from the signal corresponding to a RIBAISU cutting tool, a standard deviation sigma, and a correlation coefficient e in the branch metric (channel information) count in the Viterbi decoder 116.
[0086] Furthermore, it is as follows when it explains to a detail. Since it corresponds to the performance degradation by nonlinear factors depending on the record signal pattern on a medium, such as PE and NLTS, in the Viterbi decoder 116 of drawing 1111 , Condition Sm</SUP>0 -Sm2^(N+Q +1)-1 of xk, --, +one 2 N+Q to xk-Q is defined beforehand, and it considers as binary record signal xk-N of a past N bit and Q bits of future, --, the thing that gives this record signal-state dependency to a signal and a noise parameter.
[0087] and the after [identification] wave over condition Sm0-Sm2^(N+Q +1)-1 -- the average values d (Sm0)-d (Sm2^(N+Q +1)-1) of yk are calculated by the noise correlation operation part 114 using a RIBAISU cutting tool sequence.
[0088] With this operation gestalt, the equalizer output noise nk at the k time shall be derived by the degree type.
[0089]
[Equation 5]

$$n_k = w_k + \sum_{i=-L}^{-1} e_i(s_k^m) n_{k-i} + \sum_{i=1}^{M} e_i(s_k^m) n_{k-i} \qquad (7)$$

[0090] In addition, smk is in the condition at the k time. Moreover, the ideal identification wave over

Condition smk may be used instead of d (smk) for simplification of equipment.
[0091] As a noise model of PR channel, the identification output noise nk is a colored noise with frequency dependent, and presupposes that it has the autocorrelation of a GAUSU Markov (Gauss-Markov) sequence with the noise of L bits of past, and M bits of future, and correlation on a time-axis here. At this time, it is the output noise nk. It becomes like a degree type.
[0092]
[Equation 6]

$$\sigma^2(s_k^m)=\left\langle\left(n_k-\sum_{i=-L}^{-1}e_i(s_k^m)n_{k-i}-\sum_{i=1}^{M}e_i(s_k^m)n_{k-i}\right)^2\right\rangle \quad (8)$$

[0093] It is the white Gaussian noise by which the weight to this time of the noise of L bits of past for which e-L(smk) -e1 (smk) depended on the record condition smk, the weight to this time of the noise of M bits of future for which e1 (smk)-eM (smk) depended on the record condition smk, and wk join this time here.
[0094] wk is nk-L, --, nk-1, and nk+1, Since it did not correlate with -- and nk+L, as e-L (smk), --, e-1 (smk), and e1 (smk), --, eM (smk), it is distribution [0095] of wk.
[Equation 7]

$$\left\langle n_{k-j}\left(n_k-\sum_{i=-L}^{M}e_i(s_k^m)n_{k-i}\right)\right\rangle=R_{nn}(j\,|\,s_k^m)-\sum_{i=-L}^{M}e_i(s_k^m)R_{nn}(j-i\,|\,s_k^m)=0 \quad (-M\le i,j\le L, i\ne 0, j\ne 0) \quad (9)$$

[0096] What is necessary is just to calculate the value used as ******. However, < > expresses expected value.
[0097] Therefore, when expected value of the autocorrelation function of nk to Condition smk is made into Rnn(j |smk) = <nk nk+j| smk > and -L<=j<=M, it is [0098] from the least square method.
[Equation 8]

$$\mathbf{R}_{\backslash L+1}\left(s_k^m\right)=\begin{bmatrix}\mathbf{R}_{i,j(1\le i\le L,1\le j\le L)}\left(s_k^m\right) & \mathbf{R}_{i,j(1\le i\le L,L+2\le j\le L+M+1)}\left(s_k^m\right)\\ \mathbf{R}_{i,j(L+2\le i\le L+M+1,1\le j\le L)}\left(s_k^m\right) & \mathbf{R}_{i,j(L+2\le i\le L+M+1,L+2\le j\le L+M+1)}\left(s_k^m\right)\end{bmatrix} \quad (10)$$

[0099] What is necessary is just to ******.
[0100] therefore, x (L+M +1) (L+M +1) covariance matrix of nk -- Ri and j(smk) = the time of considering as [Rnn (j-i| smk)], 1<=i, and j<=L+M +1 -- the -- [matrix R**L +1 (smk) except L+1 line and an L+1 train component -- 0101]
[Equation 9]

$$\mathbf{e}(s_k^m)=\mathbf{R}_{\backslash L+1}^{-1}(s_k^m)\mathbf{r}(s_k^m) \quad (11)$$

[0102] ** -- carrying out -- e(smk) = (e-L (smk), --, e-1 (smk), and [e1 (smk), --, eM] (smk)) and r(smk) =(Rnn (-L| smk), --, [Rnn (-1| smk), Rnn (1| smk), --, Rnn (M| smk)]) T [if it sets -- 0103]
[Equation 10]

$$\sigma^2(s_k^m)=R_{nn}(0\,|\,s_k^m)-\mathbf{r}^{\mathrm{T}}(s_k^m)\mathbf{R}_{\backslash L+1}^{-1}(s_k^m)\mathbf{r}(s_k^m) \quad (12)$$

[0104] It is alike and e (smk) can be found more. Distributed sigma2 (smk) of white Gaussian noise wk at this time is [0105].
[Equation 11]

$$p(n_k \mid n_{k-L},\cdots,n_{k-1},n_{k+1},\cdots,n_{k+M}) = \frac{1}{\sqrt{2\pi}\,\sigma(s_k^m)}\exp\left(-\frac{\left(n_k - \sum_{i=-L}^{-1} e_i(s_k^m)n_{k-i} - \sum_{i=1}^{M} e_i(s_k^m)n_{k-i}\right)^2}{2\sigma^2(s_k^m)}\right) \quad (13)$$

[0106] It becomes.
[0107] In order to raise the precision of decode here, in branch metric count, Viterbi decoding of the noise prediction (Noise Predictive) which introduced the correlation over the noise of the past depending on a record pattern and the future is performed.
[0108] Like correlation of the noise over the condition of the signal on a medium, and a standard deviation, if e (smk) and sigma (smk) which can be found from a formula (12) and (13) shall be dependent on the condition smk of a signal, they can realize record signal-dependent noise prediction Viterbi decoding in count of channel information.
[0109] If the input noise of the Viterbi decoder 116 assumes that it is the Markov sequence with the noise which are L bits of past, and M bits of future, and correlation here, the probability density function will serve as a degree type.
[0110]
[Equation 12]

$$\Lambda_c(y_k \mid s_k^m) = -\ln\sigma(s_k^m) - \frac{\left(n_k - \sum_{i=-L}^{-1} e_i(s_k^m)n_{k-i} - \sum_{i=1}^{M} e_i(s_k^m)n_{k-i}\right)^2}{2\sigma^2(s_k^m)} \quad (14)$$

[0111] Branch metric (channel information) lambdac (yk|smk) depending on the record signal in Viterbi decoding is obtained by multiplying the right-hand side of a formula (14) by one (2pi) half, and taking the natural logarithm.
[0112]
[Equation 13]

$$\Lambda_c(y_k \mid s_k^m) = -\ln\sigma(s_k^m) - \frac{\left(y_k - d(s_k^m) - \sum_{i=-L}^{-1} e_i(s_k^m)\left(y_{k+i} - d(s_{k+i}^m)\right) - \sum_{i=1}^{M} e_i(s_k^m)\left(y_{k+i} - d(s_{k+i}^m)\right)\right)^2}{2\sigma^2(s_k^m)} \quad (15)$$

[0113] In order to calculate a formula (15), it is necessary to presume the noise of L bits of past, and M bits of future. Then, pass metric of all of section k-L -1 which passes the pass which changes to Condition sk - k+M is calculated from condition sk-1 of PR channel, and it asks for the pass with which the value serves as min.
[0114] And the averages d (Smk-L -1)-d (Smk+M) of an identification wave equivalent to the shortest pass shall be calculated, and the after [identification] noise nk shall be presumed from a formula (7). Therefore, a formula (15) turns into a degree type.
[0115]
[Equation 14]

$$\Lambda_c(y_k \mid s_k^m) = -\ln\sigma(s_k^m) - \frac{\left(y_k - d(s_k^m)\right)^2}{2\sigma^2(s_k^m)} \quad (16)$$

[0116] Thus, branch metric lambdac (yk|smk) of a formula (16) is computed from the noise figure to the condition of the past and the future which whitened, and its distribution sigma (smk), and it asks for the likelihood in Viterbi decoding from branch metric of this after that. Drawing 12 is the configuration of

the principal part of the record reversion system in the hard disk drive of drawing 2 at the time of applying this invention to the repetitive mold decode (Iterative method) proposed as new sign and decoding method replaced with Viterbi decoding in recent years. As this repetitive mold decoding method, the low consistency parity check code method (LDPC:Low Density Parity Check) and the turbo coding decrypting method are learned.

[0117] As for user data, the parity by the CRC encoder 60 and the ECC encoder 62 is first added within the hard disk controller 22. Next, by the lead channel 30, via the encoder 118 of the repetitive mold decoding method, the record compensator 64, and a driver 66, record data are sent out to a head IC 34, the write current to a recording head is generated, and it records on a magnetic disk.

[0118] On the other hand, after amplifying the analog voltage from the reproducing head by the pre amplifier of a head IC 34 first in the case of playback, it sends to the data playback section 48 of the lead channel 30, and decodes, and a decode result is returned to the hard disk controller 22, and serves as playback data through the ECC decoder 68 and the CRC decoder 70.

[0119] Drawing 13 (A) shows the basic configuration of the encoder 118 of drawing 12 , and shows the basic configuration of a decoder to drawing 13 (B).

[0120] In drawing 13 (A), an encoder 118 takes the configuration which carried out the column connection of the outside encoder 120 and the inner encoder 124. By PR channel, since it can consider that the channel itself is a convolutional code machine, it is not necessary to form the inner encoder 124 here.

[0121] The repetitive mold decoder 126 of drawing 13 (B) consists of a decoder of two ****** and ******, the inner decoder (the channel maximum a-posteriori probability decoder) 128 and the outside decoder (the outside sign maximum a-posteriori probability decoder) 132, (SISOSoft-in Soft-out). After performing repetitive decode of a predetermined time between this inner decoder 128 and the outside decoder 130, decode data are generated and outputted by threshold processing of the hard decision block 132.

[0122] That is, a point characteristic about the repetitive mold decoding method is a point of performing the maximum a-posteriori probability (MAP: Maximum a posteriori Probability), therefore neither outputs mere 0 or mere 1 flume ****** hard decision result, but two element decoders output dependability information, such as 0.4 and 0.9. In addition, the module except having indicated the configuration of the repetitive mold decoder 126 of drawing 13 , and having indicated only a part for the principal part in fact is added between components. For example, a random interleaver may be inserted between the inner decoder 126 and a decoder 130.

[0123] First, the procedure by the BCJR decoding method (Bahl-Cocke-Jeinek-Raviv) enforced with the inner decoder 128 is explained to a detail. The inner decoder 128 calculates external information lambdae (xk) using prior information lambda[from the lead signal yk from a channel, and the outside decoder 130] a (xk).

[0124] The trellis which expresses the state transition of a sign here is considered, and it asks for channel information lambdac (yk) by the degree type from the possible ideal signal mk related with the lead signal yk and its state transition for every state transition.

[0125]

[Equation 15]

$$\Lambda_c(y_k) = -\frac{1}{2\sigma^2}(y_k - m_k)^2 \qquad (17)$$

[0126] However, sigma2 are the variance of a noise.

[0127] Next, it is pass metric [to state-transition sk-1 ->sk / gamma] [0128]

[Equation 16]

$$\gamma_k(s_{k-1}, s_k) = \exp\{x_k \Lambda_a(x_k)\}\exp\{\Lambda_c(y_k)\} \qquad (18)$$

[0129] It asks. And it is [0130] by recursive count of the forward direction.

[Equation 17]

$$\alpha_k(s_k) = \sum_{s_{k-1}} \alpha_{k-1}(s_{k-1})\gamma_k(s_{k-1}, s_k) \qquad (19)$$

[0131] By recursive count of hard flow, it is [0132].
[Equation 18]

$$\beta_{k-1}(s_{k-1}) = \sum_{s_k} \beta_k(s_k)\gamma_k(s_{k-1}, s_k) \qquad (20)$$

[0133] ********. However, the termination conditions are as follows when an initial state and exit status are assumed to be conditions 0.
[0134]
[Equation 19]

$$\alpha_0(s_0) = \begin{cases} 1, & if\ s_0 = 0 \\ 0, & if\ s_0 \neq 0 \end{cases} \qquad \beta_N(s_N) = \begin{cases} 1, & if\ s_N = 0 \\ 0, & if\ s_N \neq 0 \end{cases} \qquad (21)$$

[0135] Therefore, a-posteriori probability lambda (xk) is computed by the degree type from alpha, beta, and gamma.
[0136]
[Equation 20]

$$\Lambda(x_k) = \ln \frac{\sum_{S1} \alpha_{k-1}(s_{k-1})\gamma_k(s_{k-1}, s_k)\beta_k(s_k)}{\sum_{S0} \alpha_{k-1}(s_{k-1})\gamma_k(s_{k-1}, s_k)\beta_k(s_k)} \qquad (22)$$

[0137] ********** is meant. Finally, prior information lambdaa (xk) is deducted and external information lambdae (xk) is obtained.
[0138]
[Equation 21]

$$\Lambda_e(x_k) = \Lambda(x_k) - \Lambda_a(x_k) \qquad (23)$$

[0139] The noise correlation operation part 114 which calculates the average d, and the standard deviation sigma and the correlation coefficient e of a noise of a signal from the signal sequence corresponding to a RIBAISU cutting tool is formed like the case of the Viterbi decoder of drawing 11 R> 1 also to this repetitive mold decoder 126. The inner encoder 128 asks for channel information lambdac (yk|smk) of a data area from (16) types using an average value d, and the standard deviation sigma and correlation coefficient e of a noise of a signal which were calculated by the noise correlation operation part 114, and repeats the processing outputted to the outside decoder 130 in quest of external information lambdae (xk) from (18) - (23) type.
[0140] In addition, the limitation by the numeric value which showed this invention to the above-mentioned operation gestalt, including the proper deformation which does not spoil the purpose and advantage is not received.
[0141] In the information record regenerative apparatus which records information on a magnetic-recording medium and is reproduced (Additional remark 1) At the time of data logging At the time of data playback, with the data-logging section which inserts the specific sign train beforehand set to at least two or more including the head and the backmost part of data, and is recorded on a medium The information record regenerative apparatus characterized by having a clock extract and the data playback section which performs amplitude amendment using the signal corresponding to said specific sign train after the head regenerative signal was discretized using the clock. (1)
[0142] (Additional remark 2) It is the information record regenerative apparatus characterized by reproducing after recording on a medium, without said data-logging section and the data playback section encoding user data to a RLL sign in the information record regenerative apparatus of additional remark 1 publication. (2)
[0143] (Additional remark 3) It is the information record regenerative apparatus characterized by finding

the original sampling time based on the topology which extracted the clock extract by said data playback section from the signal corresponding to said specific sign train in the information record regenerative apparatus additional remark 1 or given in two, and sampling again the signal amplitude which carried out clock synchronization by interpolation actuation of the interpolation filter by this sampling time.
[0144] In an information record regenerative apparatus additional remark 1 thru/or given in either of 3 (Additional remark 4) Said data-logging section stations a sink cutting tool in the head location of each data in which the split was carried out by said specific sign train, and records him on a medium. Said data playback section The information record regenerative apparatus characterized by detecting the sink cutting tool following said specific sign train, presuming the head bit of data, and taking the synchronization of decode.
[0145] (additional remark 5) it be the information record regenerative apparatus which said data logging section make contain a sink cutting tool in said specific sign train , record it on a medium in an information record regenerative apparatus additional remark 1 thru/or given in either of 3 , and be characterize by for said data playback section detect a sink cutting tool from said specific sign train , presume the head bit of data , and take a synchronization of a decode .
[0146] (Additional remark 6) It is the information record regenerative apparatus characterized by for said data playback section asking for the standard deviation and autocorrelation of a signal average value and a noise using the signal corresponding to said specific sign train in an information record regenerative apparatus additional remark 1 thru/or given in either of 5, and using for likelihood count of data decode.
[0147] (Additional remark 7) The information record regenerative apparatus characterized by having constituted said data-logging section and the data playback section from a signal-processing integrated circuit, and carrying said signal-processing integrated circuit in a magnetic disk drive or an optical disk unit in an information record regenerative apparatus additional remark 1 thru/or given in either of 6.
[0148] In the signal decoder circuit which records information on a magnetic-recording medium and is reproduced (Additional remark 8) At the time of data logging At the time of data playback, with the data-logging section which inserts the specific sign train beforehand set to at least two or more including the head and the backmost part of data, and is recorded on a medium The signal decoder circuit characterized by having a clock extract and the data playback section which performs amplitude amendment using the signal corresponding to said specific sign train after the head regenerative signal was discretized using the clock. (3)
[0149] (Additional remark 9) It is the signal decoder circuit characterized by reproducing after recording on a medium, without said data-logging section and the data playback section encoding user data to a RLL sign in the signal decoder circuit of additional remark 8 publication.
[0150] (Additional remark 10) It is the signal decoder circuit characterized by finding the original sampling time based on the topology which extracted the clock extract by said data playback section from the signal corresponding to said specific sign train in the signal decoder circuit additional remark 8 or given in nine, and sampling again the signal amplitude which carried out clock synchronization by interpolation actuation of the interpolation filter by this sampling time.
[0151] (additional remark 11) it be the signal decoder circuit which said data logging section station a sink cutting tool in the head location of each data in which the split be carried out by said specific sign train , record it on a medium in a signal decoder circuit additional remark 8 thru/or given in either of 10 , and be characterize by for said data playback section to detect the sink cutting tool following said specific sign train , to presume the head bit of data , and to take a synchronization of a decode .
[0152] (Additional remark 12) It be the signal decoder circuit which said data logging section make contain a sink cutting tool in said specific sign train , record it on a medium in a signal decoder circuit additional remark 8 thru/or given in either of 10 , and be characterize by for said data playback section detect a sink cutting tool from said specific sign train , presume the head bit of data , and take the synchronization of decode .
[0153] (Additional remark 13) It is the signal decoder circuit characterized by for said data playback section asking for the standard deviation and autocorrelation of a signal average value and a noise using

the signal corresponding to said specific sign train in a signal decoder circuit additional remark 8 thru/or given in either of 12, and using for likelihood count of data decode.
[0154] (Additional remark 14) The signal decoder circuit characterized by having constituted said data-logging section and the data playback section from a signal-processing integrated circuit, and carrying said signal-processing integrated circuit in a magnetic disk drive or an optical disk unit in a signal decoder circuit additional remark 8 thru/or given in either of 13.
[0155] (Additional remark 15) It is the record structure of the information record medium characterized by inserting the specific sign train beforehand set to at least two or more places in which the record signal sequence on a medium includes the head and the backmost part of data in the record structure of an information record medium. (4)
[0156] (Additional remark 16) It is the record structure of the information record medium characterized by having stationed the sink cutting tool in the head location of each data with which the split of said record signal sequence was carried out by said specific sign train in the record structure of the information record medium of additional remark 15 publication.
[0157] (Additional remark 17) It is the record structure of the information record medium characterized by said record signal sequence including a sink cutting tool in said specific sign train in the record structure of the information record medium of additional remark 15 publication.
[0158] In the information record playback approach which records information on a magnetic-recording medium and is reproduced (Additional remark 18) At the time of data logging The specific sign train beforehand set to at least two or more including the head and the backmost part of data is inserted, and it records on a medium. At the time of data playback The information record playback approach characterized by performing clock extract and amplitude amendment using the signal corresponding to said specific sign train after a head regenerative signal is discretized using a clock. (5)
[0159] (Additional remark 19) The information record playback approach characterized by reproducing after recording on a medium in the information record playback approach of additional remark 18 publication, without encoding user data to a RLL sign.
[0160] (Additional remark 20) It is the information record playback approach characterized by finding the original sampling time based on the topology which extracted the clock extract at the time of said data playback from the signal corresponding to said specific sign train in the information record playback approach additional remark 18 or given in 19, and sampling again the signal amplitude which carried out clock synchronization by interpolation actuation of the interpolation filter by this sampling time.
[0161] In the information record playback approach additional remark 18 thru/or given in either of 20 (Additional remark 21) At the time of data logging The information record playback approach characterized by stationing a sink cutting tool in the head location of each data in which the split be carried out by said specific sign train , recording on a medium , detecting the sink cutting tool following said specific sign train at the time of data playback , presuming the head bit of data , and taking the synchronization of decode .
[0162] (Additional remark 22) additional remark 18 thru/or either of 20 -- the information record playback approach characterized at the time of data logging in the information record playback approach of a publication by to include a sink cutting tool in said specific sign train, to record on a medium, to detect a sink cutting tool from said specific sign train at the time of data playback, to presume the head bit of data, and to take the synchronization of decode.
[0163] (Additional remark 23) The information record playback approach characterized by asking for the standard deviation and autocorrelation of a signal average value and a noise, and using for likelihood count of data decode using the signal corresponding to said specific sign train in the information record playback approach additional remark 18 thru/or given in either of 22 at the time of data playback.
[0164]
[Effect of the Invention] By reproducing, after inserting two or more RIBAISU cutting tools who lose the RLL sign for a clock extract or gain flattery according to this invention as explained above, change to this, and consist of a specific sign train and recording them into data Since a RIBAISU cutting tool is

a known data stream, the clock extract which did not mistake a decision value at the time of a recovery, and was stabilized even when SN of a regenerative signal was bad, and amplitude amendment are attained, and the decode engine performance (error rate) can be improved.
[0165] Moreover, since RLL decode is not performed, the error propagation by RLL decode can be lost and original ECC correction capacity can be demonstrated by this.

[Translation done.]